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Rotavirus vaccination compliance and completion in a Medicaid infant population

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ABSTRACT

We examined completion and compliance rates of rotavirus (RV) vaccination according to the recommendations of the Advisory Committee on Immunization Practices (ACIP) and the Food and Drug Administration approved Prescribing Information (PI) for *Rotarix*® (RV1, GlaxoSmithKline Vaccines) and *RotaTeq*® (RV5, Merck and Co.) among infants under one year of age covered by Medicaid programs. Healthcare claims data from state Medicaid programs that constituted the *Truven Health MarketScan*® Multi-State Medicaid Database were retrieved from May 2008–June 2012. Infants were grouped under PI and ACIP cohorts based on the dosing regimens followed. The overall compliance per PI ($n = 673,956$) and ACIP ($n = 695,612$) recommendations were 24.5% and 28.2%, respectively; completion rates were 30.3% and 32.6%, respectively. In the PI cohort, infants who received RV1 had significantly higher compliance as compared with infants who received RV5 (65.2% vs. 31.3%; $p < 0.0001$); completion rates among infants receiving RV1 and RV5 were 65.3% and 46.4%, respectively ($p < 0.0001$). In the ACIP cohort, compliance with RV1 was significantly higher than RV5 (68.8% vs. 45.9%; $p < 0.0001$) as was the overall completion rate (73.5% vs. 48.8%; $p < 0.0001$). While compliance is increasing year over year, overall compliance of RV vaccines is suboptimal, with over 40% of eligible infants unvaccinated in both populations. The 2-dose RV vaccine showed better completion rates and higher compliance than the 3-dose RV vaccine in the United States. Public health initiatives focusing on suboptimal compliance and completion rates of RV vaccination in the Medicaid population could improve these metrics, thereby offering protection against RV infection.

1. Introduction

Rotavirus (RV) is one of the leading causes of gastroenteritis (GE) (vomiting and diarrhea) in small children less than five years of age [1]. Globally, it has been estimated that RV at one time accounted for nearly 611,000 diarrheal deaths and 39% of diarrheal hospitalizations in children aged less than five years annually [2]. Deaths in the United States (US) were estimated to be uncommon with only 20–40 occurring annually before the initiation of the RV vaccination program in 2006 [3]. However the direct costs due to RV were estimated to be $300 million annually with 55,000–70,000 hospitalizations, 200,000 emergency department visits, and 400,000 outpatient visits each year among children less than five years old [3]. When indirect costs were added, the total annual costs were estimated at more than $1 billion [3].

Two vaccines are currently approved by the Food and Drug Administration (FDA) for the prevention of rotavirus gastroenteritis (RVGE) among infants in the US [4]. The oral pentavalent vaccine, *RotaTeq*® (RV5, Merck and Co.) was approved as a three-dose series in February 2006, and the oral monovalent vaccine, *Rotarix*® (RV1, GlaxoSmithKline Vaccines) was approved as a two-dose series in April 2008. In response to the approval of RV5, the Centers for Disease Control and Prevention (CDC) Advisory Committee on Immunization Practices (ACIP) recommended routine vaccination with RV5 given orally at ages two, four, and six months in 2006 [4]. However, prescribing information (PI) for RV5 states the first dose is to be given starting at 6–12 weeks of age, with the subsequent doses given at 4–10-week intervals, and the last dose should not be given after 32 weeks of age [5]. In 2009, the ACIP updated these recommendations to include vaccination with

Abbreviations: ACIP, Advisory Committee on Immunization Practices; CDC, Centers for Disease Control and Prevention; CPT, Current Procedural Terminology; DTaP, diphtheria, tetanus toxoids, and acellular pertussis; FDA, Food and Drug Administration; GE, gastroenteritis; HMO, Health Maintenance Organization; NIS, National Immunization Survey; PI, prescribing information; RV, rotavirus; RVGE, rotavirus gastroenteritis; UPP, Universal Purchase Programs; US, United States.

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RV1 given orally at ages two months and four months [6]. The RV1 PI, however, states the first dose of RV1 is to be given no earlier than six weeks of age and the second (i.e., last) dose at least four weeks later, but before 24 weeks of age [7]. A study of adherence to the 2006 ACIP RV5 dosing schedules for the first three months following vaccine availability found that 51% of infants received their first dose outside the recommended age window [8]. Another study after the first six months of RV vaccine implementation found 20% of infants received their first dose outside the recommended window [9]. Recent studies also evaluated the rates of adherence (i.e., compliance) to both the ACIP and FDA-approved dosing schedules for RV1 and RV5 among infants in the US. One study included infants less than one year of age enrolled in managed care plans and initiating RV vaccination during the months January to June of 2009 [10]. Overall, 61.2% of the population were compliant with the PI dosing schedules (RV1 75.0% vs. RV5 59.5%; $p < 0.001$) and 77.2% were compliant with the ACIP dosing schedule (RV1 83.3% vs. RV5 76.4%; $p < 0.001$). Completion rate, defined as receiving all doses but not necessarily on schedule, was 84.3% (RV1 91.0% vs. RV5 83.4%; $p < 0.001$) [10]. Two recent studies on privately insured children also found higher compliance and completion rates among children receiving RV1 than those receiving RV5 [11,12].

The 2012 National Immunization Survey (NIS) released by the CDC monitored the vaccination coverage among children up through 19–35 months [13]. Significant differences were found by race (White 70.5% vs. Black 60.4%; $p < 0.05$) and poverty status (below pervert level 63.4% vs. above poverty level 71.6%; $p < 0.05$) [13]. In a large privately-insured population, between 78 and 83% of eligible infants received at least one RV vaccine per month in 2009–2010 [11]. Both Panozzo et al. [11] and Krishnarajah et al. [12] found that among infants receiving at least one rotavirus vaccine, the completion rate was higher among those receiving RV1 as compared to those receiving RV5 (Panozzo et al: 87% vs.79%, $p < 0.01$; Krishnarajah et al: 91% vs. 83%, $p < 0.01$). There is currently no information on completion or compliance rates of RV vaccination within the Medicaid population. The purpose of the current study therefore was to examine RV vaccination completion and compliance rates with both the ACIP recommendations and FDA approved PI schedule overall and for RV1 and RV5 separately among infants less than one year of age enrolled in a large number of Medicaid programs. This study also estimated the proportion of infants who remained unvaccinated and identified the possible infant and plan level predictors of compliance with the PI.

2. Methods

2.1. Data source

This study was a retrospective observational cohort study using administrative healthcare claims data from state Medicaid programs that constituted the *Truven Health MarketScan*® Multi-State Medicaid Database for the period May 1, 2008 to June 30, 2012. The database reflects the healthcare service use (medical and pharmacy claims) of over 6.7 million individuals covered by Medicaid programs in 10–13 geographically dispersed states within a given year. Medicaid data were collected from states with and without Universal Purchase Programs (UPP). Because of confidentiality agreements, we are unable to reveal the states, but were able to identify the UPP status of the states that contributed to the database. Enrollees were those covered under fee-for-service and managed care plans, for whom monthly eligibility data, federal aid category data (i.e., income based, disability, temporary assistance for needy families) and racial information were available. Due to contractual obligations, the specific states contributing data to the database were not reported.

2.2. Study populations

Due to differences in PI and ACIP recommendations for the administration schedule of rotavirus vaccines, two separate populations of infants were defined. Separate analyses were conducted for the following cohorts: all states (i.e., both UPP and non-UPP states), and non-UPP states only. Age at the time of RV vaccination was based on the service date on the claim for the first dose and the birth date. Vaccine type was identified by the Current Procedural Terminology (CPT) codes on outpatient medical claims.

2.2.1. PI population

Infants in the PI population, born between May 1, 2008 and December 31, 2011 were identified and grouped into three cohorts:

(1) infants with at least one claim for RV1 (RV1-PI);
(2) infants with at least one claim for RV5 (RV5-PI); and
(3) infants not receiving any doses of RV1 or RV5.

Eligible infants were further required to have continuous enrollment in medical and pharmacy benefits for at least 24 weeks from birth for the RV1 cohort and for at least 32 weeks from birth for the RV5 cohort. Infants who had evidence of receiving more than one brand (RV1 and RV5) of vaccine in their series were excluded from the PI cohorts. Infants who had received RV1 or RV5 before six weeks of age were also excluded.

2.2.2. ACIP population

Infants of the ACIP population selected for analysis were born between May 1, 2008 and October 31, 2011 and continuously enrolled in medical and pharmacy benefits from birth to eight months of age. Infants receiving a mixed regimen of RV vaccines (at least one dose of RV1 and one dose of RV5) were included. Four cohorts identified for the ACIP analysis were:

(1) infants with at least one claim for RV1 and no claims for RV5;
(2) infants with at least one claim for RV5 and no claim for RV1;
(3) infants with claims for both RV1 and RV5 [6]; and
(4) infants who did not have evidence of receiving either RV1 or RV5.

Infants who had received RV1 or RV5 before six weeks of age were excluded.

2.3. Compliance and completion

Compliance to each RV dose was assessed in accordance with the corresponding PI or ACIP schedules as described in Table 1. Individual infants were categorized as “compliant” if he/she received all doses in accordance with the recommended schedule.

Completion was defined as receipt of two doses of RV1, three doses of RV5, or for the ACIP-mixed cohort one dose of RV1 and two doses of RV5 in any order. Whether infants received three doses of diphtheria, tetanus toxoids, and acellular pertussis (DTaP) vaccine was also assessed. The DTaP vaccine was selected because the recommended timing overlaps with the first 2 (2 months and 4 months) or 3 (2 months, 4 months and 6 months) doses of rotavirus vaccine.

2.4. Statistical analyses

Baseline characteristics were summarized by population (PI or ACIP) and cohort (RV1, RV5, Mixed, None) using frequency and percentage for categorical variables and mean and standard deviation for continuous variables. Statistical significance was evaluated

Table 1
Rotavirus vaccine dosing schedules.

Vaccine dose	Recommendations		
	PI[a]		ACIP[b]
	RV5	RV1	
Minimum age for first dose	6 Weeks + 6 days	6 Weeks + 6 days	6 Weeks
Maximum age for any dose	32 Weeks	24 Weeks	8 Months and 0 days
Dose 1	6 Weeks through 12 weeks	6 Weeks through 20 weeks	6 Weeks through 14 weeks and 6 days
Dose 2	4–10 Weeks after the previous dose	≥4 Weeks after the previous dose	Age 4 months and ≥4 weeks after the previous dose
Dose 3	4–10 Weeks after the previous dose	N/A	6 Months and ≥4 weeks after the previous dose

[a] Prescribing information approved by the Food and Drug Administration.
[b] Advisory Committee on Immunization Practices.

using chi-square tests and one-way analysis of variance. Differences were considered statistically significant if the two-sided *p*-value was 0.05 or less.

Predictors of PI compliance for RV vaccination were identified using multivariable log-binomial models on RV1 and RV5 cohorts. The primary predictors of interest were vaccine received (RV5 was used as the reference group) and year of birth; and interactions between vaccine type and year of birth. Other covariates included were gender, plan type, race, and an indicator of receipt of three doses of diphtheria, tetanus toxoids, and acellular pertussis (DTaP) vaccine. The risk ratios of the parameter estimates with 95% confidence intervals are presented for all model predictors.

All analyses were run separately for all identified infants and those infants not living in Medicaid states with UPP that included RV1 and RV5.

3. Results

While analyses of infants residing in all available states and only in non-UPP states were both conducted, results were similar. In addition, infants from non-UPP states accounted for over 90% of eligible infants from all states. As such, only the results for the non-UPP resident population are presented here.

3.1. PI population

Of the 673,956 infants who qualified for the PI population 51% were male; 59.3% were enrolled in capitated Health Maintenance Organization (HMO) plans, 40.7% fee-for-service (of which 0.9% were of other/unknown plans); 49.4% were White, 32.5% Black, 6.0% Hispanic, and 2.8% other and 9.3% of unknown race.

Nearly 43% of infants ($n = 287,676$) did not have claims for either RV1 or RV5 but the proportion of unvaccinated infants declined from 50% in 2008 to 33% in 2011. On analysis by race, more than one-half of Hispanic infants were unvaccinated (54%), followed by Black (45%) and White (39%) infants ($p < 0.0001$) (Table 2).

Overall, 57% ($n = 386,280$) of the PI population received RV vaccination. Specifically, 19% ($n = 130,928$) had one or more claims for RV1 and 38% ($n = 255,352$) had one or more claims for RV5. The proportion of infants vaccinated with at least one dose of RV1 increased from 2% in 2008 to 30% in 2011 and those with at least one dose of RV5 decreased from 49% in 2008 to 38% in 2011.

In the PI population, 24.5% ($n = 165,322$) were fully compliant and compliance rate increased from 2008 (19.2%) to 2011 (32.6%). Hispanic infants had the lowest identified rate of compliance (16.9%), followed by black infants (21.6%), and White infants (28.5%; $p < 0.0001$). No differences in compliance by infant gender were found.

When stratified by RV type, infants who received the first dose of RV1 had a significantly higher compliance rate than infants who received the first dose of RV5 (65.2% vs. 31.3%; $p < 0.0001$). Evaluating non-compliance by dose, the RV5 cohort had a significantly higher rate of first dose non-compliance compared with the RV1 cohort (20.1% vs. 1.9%; $p < 0.0001$). Similarly, non-compliance with the second dose was significantly higher in the RV5 (49.2%) compared with the RV1 (34.8%; $p < 0.0001$) cohort (Table 2).

Less than a third (30.3%) of infants completed all required doses of RV vaccines. Completion rates among infants receiving RV1 were 1.4 times those receiving RV5. Among infants receiving RV1 65.3% completed both doses, and among infants receiving RV5, completion of all three doses was 46.4% ($p < 0.0001$). While, RV5-PI completion was less than 50%, of the 255,352 infants having at least one RV5 dose, 79.1% ($n = 202,066$) received at least the second dose and among these, 58.6% ($n = 118,467$) received the third dose.

Results of the multivariable analysis evaluating predictors of PI compliance are presented in Table 3. Infants who received DTaP vaccination had a higher likelihood of RV vaccination-PI compliance (risk ratio = 17.8 [95% confidence interval: 17.4–18.3]). For infants born in 2008, those receiving one dose of RV1 were 1.4 times as likely to be compliant as those receiving at least one dose of RV5.

3.2. ACIP population

After applying the ACIP criteria for cohort selection, 118,555 (17%) subjects received RV1; 250,188 (36%) subjects received RV5; 46,067 (6.6%) had claims for both RV1 and RV5 vaccines (mixed); and 280,802 (40.4%) did not have claims for either RV vaccine. Results for the ACIP population ($n = 695,612$) were largely similar to those of the PI population. The majority of infants were White (49.8%) followed by Black (32.6%) and Hispanic (5.8%). Almost all infants received RV vaccines also received DTaP vaccination (99.4% in RV1 cohort and 98.2% in RV5 cohort) (Table 4).

Overall 40.4% of the ACIP population did not receive RV vaccines, and the proportion decreased from 48% in 2008 to 32% in 2011 ($p < 0.0001$). The highest proportion of unvaccinated infants in the ACIP population was observed in Hispanic infants (52%), followed by Black (42%) and White (36%) infants ($p < 0.0001$) (Table 4).

Over a quarter (28.2%, $n = 196,500$) of ACIP population were fully compliant and compliance rate for RV1 recipients (68.8%) was significantly higher than that for RV5 recipients (45.9%; $p < 0.0001$) (Table 4). Overall completion rate of RV vaccination was 32.6% ($n = 226,537$). The completion rate in RV1 cohort was 1.5 times as RV5 cohort: 73.5% of RV1 cohort completed two required doses, and 48.8% of the RV5 cohort completed three required doses. In the mixed cohort, 37.9% of the infants completed all three required doses ($p < 0.0001$).

4. Discussion

The goal of the current analysis was to examine compliance, and completion rates of rotavirus vaccination overall and by type of vaccine (*Rotarix*® and *RotaTeq*®) based on FDA package insert and CDC-ACIP recommendations, and predictors of overall PI compliance among infants enrolled in Medicaid health plans. Results

Table 2
Compliance to dosing schedule per PI and completion rates (n^a = 673,956).

Compliance per PI and completion	All infants (n^b = 673,956)		RV1 (n = 130,928)		RV5 (n = 255,352)		Infants with No RV vaccine (n = 287,676)		p-Value[d] RV1 vs. RV5
	n	%[c]	n	%	n	%	n	%	
Age in weeks at initiation (Mean, SD[e])	11.1	4.4	10.7	3.4	11.3	4.8	NA[f]	NA	<0.0001
Age in weeks at completion (Mean, SD)	23.7	4.6	18.6	1.7	27.3	1.7	NA	NA	<0.0001
				Vaccinations rates (n, %)					
Overall	673,956	100.0	130,928	19.4	255,352	37.9	287,676	42.7	
By birth year									<0.0001
2008	122,561	100.0	2456	2.0	59,381	48.5	60,724	49.5	
2009	205,006	100.0	39,781	19.4	67,164	32.8	98,061	47.8	
2010	183,516	100.0	40,161	21.9	67,568	36.8	75,787	41.3	
2011	162,873	100.0	48,530	29.8	61,239	37.6	53,104	32.6	
By race									
White	333,012	100.0	69,688	20.9	135,039	40.6	128,285	38.5	<0.0001
Black	218,833	100.0	45,830	20.9	75,614	34.6	97,389	44.5	
Hispanic	40,328	100.0	3741	9.3	14,905	37.0	21,682	53.8	
Other	19,193	100.0	3962	20.6	8482	44.2	6749	35.2	
Unknown	62,590	100.0	7707	12.3	21,312	34.1	33,571	53.6	
				Infants fully compliant (n, %)					
Overall (n, %)	165,322	24.5	85,376	65.2	79,946	31.3	NA	NA	<0.0001
By birth year									
2008	23,591	19.2	1426	58.1	22,165	37.3	NA	NA	<0.0001
2009	41,525	20.3	24,502	61.6	17,023	25.3	NA	NA	<0.0001
2010	47,056	25.6	26,192	65.2	20,864	30.9	NA	NA	<0.0001
2011	53,150	32.6	33,256	68.5	19,894	32.5	NA	NA	<0.0001
By race									
White	94,851	28.5	47,382	68.0	47,469	35.2			<0.0001
Black	47,287	21.6	28,451	62.1	18,836	24.9	NA	NA	
Hispanic	6812	16.9	2100	56.1	4712	31.6			
Other	5333	27.8	2653	67.0	2680	31.6	NA	NA	
Unknown	11,039	17.6	4790	62.2	6249	29.3			
				Infants who are non-compliant, by dose (n, %)					
Number of infants who were non-compliant with the first dose	53,773	8.0	2480	1.9	51,293	20.1	NA	NA	<0.0001
Number of infants who were non-compliant with the second dose	171,227	25.4	45,552	34.8	125,675	49.2	NA	NA	<0.0001
Number of infants who were non-compliant with the third dose	175,406	26.0	NA	NA	175,406	68.7	NA	NA	
				Completion rate (n, %)					
Infants who completed all doses	203,952	30.3	85,485	65.3	118,467	46.4	NA	NA	<0.0001
By dose									
Number of infants who received only the first dose	98,729	14.6	45,443	34.7	53,286	20.9	NA	NA	<0.0001

Table 2 (*Continued*)

Compliance per PI and completion	All infants (n[b] = 673,956)		RV1 (n = 130,928)		RV5 (n = 255,352)		Infants with No RV vaccine (n = 287,676)		p-Value[d] RV1 vs. RV5
	n	%[c]	n	%	n	%	n	%	
Number of infants who received the first and the second doses only	83,599	12.4	85,485	65.3	83,599	32.7	NA	NA	
Number of infants who received the first, second and third doses	NA	NA	NA	NA	118,467	46.4	NA	NA	<0.0001

[a] Total number of infants.
[b] Number of infants in each category.
[c] Percentage of infants in each category.
[d] p-Value calculated using chi-square tests and one-way analysis of variance.
[e] Standard deviation.
[f] Not applicable.

show that despite increasing national vaccination coverage for RV vaccines, a sizeable proportion of Medicaid infants in the states providing data to the study database either do not get vaccinated at all or do not receive their vaccinations according to either of the recommended schedules. Racial disparities also exist with more than one-half of Hispanic infants being unvaccinated while 39% of White infants were not vaccinated between 2008 and 2011. In addition disparities exist depending on the type of health plan infants are enrolled in, with fee-for-service plans having greater non-vaccination rates than those enrolled in HMOs.

In our study, overall RV vaccination compliance rate was found to be 24.5% per PI and 28.2% per ACIP recommendation; the overall completion rate was 30.3% in the PI population and 32.6% in the ACIP population. While not largely different from each other, more patients were compliant to ACIP recommendations potentially due to efforts to harmonize a single dosing schedule. While overall completion rates were relatively low, getting the first vaccine in the series was found to increase the chances of getting the second (for RV1 and RV5) and third (for RV5) doses. In the PI population, we found 43% of infants without either RV1 or RV5 vaccines and in the ACIP population the proportion of unvaccinated infants was 40%. Compliance and completion per PI and ACIP recommendations were both found to be significantly greater among infants receiving RV1 than those receiving RV5.

These results are in contrast to those reported by the NIS which estimates RV vaccination coverage between Q1 2012 and Q4 2012 in infants born between January 2009 and May 2011. The survey found approximately 68.6% of participants to have received either two doses of RV1 or all three doses of RV5 [13]. The NIS sample included infants enrolled in privately and publicly sponsored health plans as well as infants who were uninsured or under insured. While there may be some selection bias associated with the NIS, the mix of payers may account for much of the discrepancy. Furthermore, the children included in the survey were older (19–35 months) [13] than those included in our study (6–8 months), which may further explain the difference in coverage rates. However, the difference in RV vaccination coverage by poverty status and racial background observed in our study was similar to that reported in the NIS [13].

According to the 2012 Annual Report on the Quality of Care for Children in Medicaid and Children's Health Insurance Program, younger children with public coverage appear to lag behind privately insured children on rates of well-child visits and immunizations [14]. The reasons for this are numerous but infants

Table 3
Multivariate model of PI compliance with interaction terms.

Variable	Relative risk	95% Confidence interval around relative risk	p-Value[a]
RV1	1.402	1.371–1.433	<0.001
Female	0.999	0.995–1.002	0.470
Birth year (ref = 2008)			
Year 2009	0.794	0.783–0.805	<0.001
Year 2010	0.885	0.873–0.896	<0.001
Year 2011	0.928	0.916–0.940	<0.001
Race (ref = white)			
Black	0.957	0.952–0.961	<0.001
Hispanic	0.980	0.970–0.989	<0.001
Other race	0.993	0.983–1.003	0.147
Missing race	0.992	0.985–0.999	0.031
Plan type (ref = comprehensive)			
Health Maintenance Organization (HMO)	0.999	0.995–1.002	0.488
Unknown plan type	1.033	1.010–1.057	0.004
3-Dose DTaP vaccines within 24 (RV1) or 32 weeks (RV5 or neither)	17.805	17.336–18.287	<0.001
Vaccine × year interaction			
RV1 × year 2009	1.228	1.197–1.260	<0.001
RV1 × year 2010	1.205	1.176–1.235	<0.001
RV1 × year 2011	1.208	1.179–1.237	<0.001

Note: sample is restricted to non-UPP infants.
[a] p-Value calculated using chi-square tests and one-way analysis of variance.

Table 4
Compliance to dosing schedule per ACIP and completion rates (n^a = 695,612).

Compliance per ACIP and completion	Infants who had at least 1 RV vaccine (n^b = 414,810)		RV1 (n = 118,555)		RV5 (n = 250,188)		p-Value[e] RV1 vs. RV5	Mixed RV1 and RV5 (n = 46,067)		p-Value RV1 vs. RV5 vs. Mixed	Infants with No RV vaccine (n = 280,802)	
	n	%[c]	n	%	n	%		n	%		n	%
Receipt of other vaccines (n, %)												
DTaP vaccination (any)	409,646	58.9	117,836	99.4	245,774	98.2	<0.0001	46,036	99.9	<0.0001	70,242	25.0
DTaP vaccination (completed)	255,507	36.7	73,176	61.7	146,940	58.7	<0.0001	35,391	76.8	<0.0001	22,036	7.8
Age in weeks at initiation (Mean, SD)[d]	11.2	4.6	11.2	4.3	11.4	4.9	<0.0001	9.9	2.5	<0.0001	NA	NA
Age in weeks at completion (Mean, SD)	24.5	4.7	19.6	3.3	27.6	2.0	<0.0001	27.7	2.3	<0.0001	NA	NA
Vaccination rates												
Overall	695,612		118,555	17.0	250,188	36.0		46,067	6.6		280,802	40.4
By birth year												
2008	125,425	100.0	2505	2.0	59,176	47.2	<0.0001	3527	2.8	<0.0001	60,217	48.0
2009	219,129	100.0	37,173	17.0	66,578	30.4		18,392	8.4		96,986	44.3
2010	195,218	100.0	39,251	20.1	67,305	34.5		14,276	7.3		74,386	38.1
2011	155,840	100.0	39,626	25.4	57,129	36.7		9872	6.3		49,213	31.6
By race												
White	346,499	100.0	63,623	18.4	132,475	38.2	<0.0001	25,075	7.2	NA	125,326	36.2
Black	226,900	100.0	41,452	18.3	73,983	32.6		16,211	7.1	NA	95,254	42.0
Hispanic	40,382	100.0	3449	8.5	14,662	36.3		1172	2.9	NA	21,099	52.2
Other	19,809	100.0	3556	18.0	8325	42.0		1390	7.0	NA	6538	33.0
Unknown	62,022	100.0	6475	10.4	20,743	33.4		2219	3.6	NA	32,585	52.5
Infants fully compliant (n, %)												
Overall	196,500	28.2	81,594	68.8	114,906	45.9	<0.0001	NA	NA	NA	NA	NA
By birth year												
2008	34,016	27.1	1400	55.9	32,616	55.1	<0.4471	NA	NA	NA	NA	NA
2009	50,040	22.8	25,220	67.8	24,820	37.3	<0.0001	NA	NA	NA	NA	NA
2010	57,496	29.5	26,810	68.3	30,686	45.6	<0.0001	NA	NA	NA	NA	NA
2011	54,948	35.3	28,164	71.1	26,784	46.9	<0.0001	NA	NA	NA	NA	NA
By race												
White	112,289	32.4	45,475	71.5	66,814	50.4	NA	NA	NA	NA	NA	NA
Black	56,409	24.9	27,626	66.6	28,783	38.9	NA	NA	NA	NA		
Hispanic	8756	21.7	1909	55.3	6847	46.7	NA	NA	NA	NA	NA	NA
Other	6205	31.3	2474	69.6	3731	44.8	NA	NA	NA	NA	NA	NA
Unknown	12,841	20.7	4110	63.5	8731	42.1	NA	NA	NA	NA	NA	NA
Infants who are non-compliant, by dose (n, %)												
Number of infants who missed the first dose	60,622	8.7	18,750	15.8	41,872	16.7	<0.0001	NA	NA	NA	NA	NA
Number of infants who missed the second dose	111,664	16.1	36,961	31.2	74,703	29.9	<0.0001	NA	NA	NA	NA	NA
Number of infants who missed the third dose	135,282	19.4			135,282	54.1		NA	NA	NA	NA	NA
Infants who completed their doses (n, %)												
Number of infants who received all doses	226,537	32.6	87,085	73.5	121,973	48.8	<0.0001	17,479	37.9	<0.0001	NA	NA
Number of infants who received only the first dose	81,862	11.8	31,470	26.5	50,392	20.1	<0.0001	NA	NA	NA	NA	NA
Number of infants who received the first and the second doses only	77,823	11.2	87,085	73.5	77,823	31.1	NA	NA	NA	NA	NA	NA
Number of infants who first, second and third doses	NA	NA	NA	NA	121,973	48.8	<0.0001	17,479	37.9	<0.0001	NA	NA

[a] Total number of infants.
[b] Number of infants in each category.
[c] Percentage of infants in each category.
[d] Standard deviation.
[e] p-Value.

with Medicaid coverage are less likely to have a usual healthcare provider with night or weekend hours and their parents or guardians are less likely to have transportation to the doctor's office or clinic [15,16]. These barriers not only impact the receipt of vaccination but also the timing of vaccinations. While not a focus of this analysis, RV vaccination results as compared to those reported in the NIS are similar to results of DTaP immunization in the two datasets. The DTaP completion rate in this study was 36.7% by 32 weeks (eight months) whereas the reported NIS completion rate was 69.7% by seven months of age [17]. These results suggest that the differences observed for RV vaccination are not unique and the reasons underpinning these discrepancies are again largely based on differences in the underlying populations. After accounting for other infant and plan characteristics, infants completing the DTaP vaccination series were more likely to be compliant with RV vaccination. In the unadjusted analyses, following the receipt of the first dose of RV vaccine, compliance with the first dose of either RV1 or RV5 resulted in high proportions of infants receiving the second dose of either, and among those on the 3-dose regimen, subsequently completing the vaccine schedule.

Interestingly, in the PI population non-compliance for the first dose of RV1 was significantly lower compared with RV5 (1.9% vs. 20.1%; $p < 0.0001$). One explanation for this large difference could be attributable to the recommended time windows for giving the first dose listed in the each of the PIs as the window for giving the first RV1 dose is eight weeks wider than that for RV5 (RV1: 6–20 weeks vs. RV5: 6–12 weeks). While assessing the completion of RV, less emphasis was given to the timing of individual RV doses than on the assessment of compliance. The RV1 cohort also had a significantly higher completion rate than the RV5 cohort (65.3% vs. 46.4%, $p < 0.001$) by the age of 8 months, which is mainly attributable to the fewer doses required by RV1 series.

There are several limitations to these analyses. First, administrative claims data are generated for the purposes of provider reimbursement and not for this study. Information derived from medical billing codes may be subject to omissions, errors, or other differences in billing and reimbursement practices of physician offices and individual state Medicaid programs. Presence of RV1 and RV5 was identified by using CPT codes on medical claims, as opposed to medical records. There is also the potential for selection bias as a result of the process by which the analytic sample was selected. For example, the continuous eligibility criterion requires the study infants to have at least eight months of medical and pharmacy benefits from their date of birth. While this criterion allows for more meaningful comparisons between the study cohorts, those infants who had intermittent healthcare coverage were not examined. As noted, the study population comprised infants with Medicaid coverage in the subset of US states contained in the *Truven Health MarketScan*® Multi-State Medicaid Database with and without UPPs. Thus, the results may not be representative of all infants enrolled in all Medicaid programs across the United States.

5. Conclusion

A large proportion of infants in the US remain unvaccinated. The proportion of infants that completed the RV vaccination series was higher among recipients of RV1 than RV5. RV1 recipients also showed higher compliance with both the PI and ACIP recommendations relative to RV5 recipients. Infants vaccinated with DTaP vaccine had a higher likelihood of compliance with RV vaccination. Despite CDC recommendations, RV vaccine is underutilized in US Medicaid recipients with as many as 40% of eligible infants unvaccinated. Public health initiatives to increase completion and compliance with vaccine recommendations may help improve vaccination initiation, completion and compliance rates among infants who need protection against RV infection and reduce the states cost burden in providing care to infants with RV infection.

Trademark statements

Rotarix is a registered trademark of GlaxoSmithKline group of companies. *Rotateq* is a trademark of Merck & Co., Inc. *Truven Health MarketScan* is a trademark of Truven Health Analytics Inc.

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Contributorship

All authors participated in the design or implementation or analysis, and interpretation of the study; and the development of this manuscript. All authors had full access to the data and gave final approval before submission. All authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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